ANALYSIS OF SEDIMENT COLLECTION TROUGH PROCEDURE INCORPORATING RUNOFF DATA

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BY

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ON ROTATION ASSIGNMENT TO

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and

FOREWORD

The Water Quality and Solid Waste Section of the Enviro-Chemical Branch, TransLab, provides assistance and direction to the districts for evaluating potential water quality problems associated with slope erosion. Studies are undertaken on various projects to measure erosion rates. This information is not only helpful in estimating erosion quantities but is also used to design appropriate mitigation measures in keeping with Caltrans "Best Management Practices for Control of Water Pollution (Transportation Activities)", dated May 1979.

TransLab has used various methods to estimate erosion potentials. One of the quantitative methods is the sediment collection trough procedure. The method compares the accumulated amount of sediment from a slope against the accumulated amount of precipitation. The resulting sediment rating curve is then used to estimate the average annual erosion rate for the average annual precipitation at a given slope.

Questions have arisen over the repeatability of data from this method, whether the amount of water runoff is important in the movement of sediment and scour (i.e., development of rills), and whether other factors have an important role in determining the "average" erosion rate.

TransLab has an HP&R research project entitled "Methods of Measuring and Controlling Erosion from Road Slopes" (E80TL12) scheduled to begin in FY 81-82. The study presented in this report provides useful background information for preparing the research Work Plan for the E80TL12 project.

The study was conducted by Richard (Rick) Jorgensen, Jr. Civil Engineer, during his six-month rotation assignment in the Water Quality and Solid Waste Section at TransLab. The work was conducted under the supervision of Douglas Parks, supervisor of the Physical Investigations Unit, and under the direction of Richard Howell, supervisor of the Water Quality and Solid Waste Research and Development Section.

TABLE OF CONTENTS

INTRODUCTION

As a six-month project (July-December 1980) while on rotation at the Transportation Laboratory, Water Quality Section, Richard (Rick) Jorgensen (Jr. Civil Engineer) conducted a study to investigate sediment collection trough measurement methods (see Appendix A). The correlations between runoff, rainfall and sediment yield were studied in an attempt to obtain a more accurate method of using a sediment collection trough to estimate erosion rates for road slopes.

The investigation began with a literature search for related material and background information. This search yielded sufficient background, but little information about incorporating runoff data into this type of analysis.

The National Park Service (NPS) provided the raw data from two of their collection troughs (sediment and runoff) in the Redwood National Park of Northern California. These data were incomplete because runoff quantities for 11 of the 26 sample periods were missing. The collection troughs used by NPS were undersized. The rainfall and sediment yield data that were available were correlated to generate rainfall/sediment yield prediction curves.

First, an attempt was made to correlate the incomplete runoff data with the rainfall and sediment yield data. This attempt failed because runoff is dependent on other variables which have a cumulative effect on the correlation. Next, the missing runoff data were generated from correlations with known runoff data and our other data. This also proved unsuccessful because there were no large storm runoff data and the use of small storm runoff data yielded unrealistic results.

Finally, Dr. Frank Caruccio of the University of South Carolina, Department of Geology, was contacted as another possible source of sediment/runoff data. He conducted a study that analyzed runoff for sediment content. His troughs also overflowed and thus yielded no total runoff information.

At this point it became obvious that without another data base the objective of this study could not be adequately addressed. On October 2, 1980, the study was discontinued and this report was prepared.

This report is a summary of the work completed and the conclusions that could be drawn from the abbreviated study.

CONCLUSIONS

1. With the data available, the objective of the study could not be met.

2. For this case, the results of the conventional analysis to estimate erosion should be satisfactory, as shown by the results of the statistical analysis on the cumulative rainfall versus cumulative sediment yield curve.

3. The literature search brought to light the availability of forms of the Universal Soil Loss Equation (USLE) that are applicable to highway slopes. These methods should also be investigated as erosion prediction methods in addition to the sediment collection trough method.

RECOMMENDATIONS

1. An interesting project would consist of using the USLE from NCHRP Report 220, "Erosion Control During Highway Construction", to predict erosion from a slope. Then, the erosion could be measured with sediment collection troughs and the results compared. This project should be under taken.

LITERATURE SEARCH

The literature search was begun by John Ehsan, also a Jr. Civil Engineer on rotation, in 1980. John was originally assigned to this project, but was soon reassigned to another project on refertilization of road slopes for erosion control. The emphasis of his search was more related to erosion control rather than erosion prediction or estimation. His literature search yielded little information concerning this study. Thus, the information available for use came primarily from the TransLab library in the form of reports on erosion authored by TransLab personnel.

As the study progressed, information that seemed related to this project, if not specifically to this study, kept surfacing. At this point, it was decided to conduct another literature search directed more toward the research project. This search was aimed at acquiring data related to erosion prediction methods and specifically the relationship of runoff to erosion predictions. This search yielded substantial information about erosion prediction and runoff, but it was all in reference to the Universal Soil Loss Equation, in which one component is a runoff factor.

While not directly related to the study, much of the information about the Universal Soil Loss Equation might be worth noting. Also of interest to those investigating erosion prediction might be the Transportation Research Board's reports 220 and 221 "Erosion Control During Highway Construction".

DATA

The data used in this study were provided by Bill Weaver of the National Park Service Office in Arcata, California. The data came from two sediment collection troughs located near Bridge Creek in the Redwood National Park. The plots on which the troughs were placed were in the C-Horizon (Masterson soil series). They had slopes of approximately 65% and both had a southern aspect. Trough 1 had an area of 222 ft^2 while trough 2 had an area of 225 ft^2.

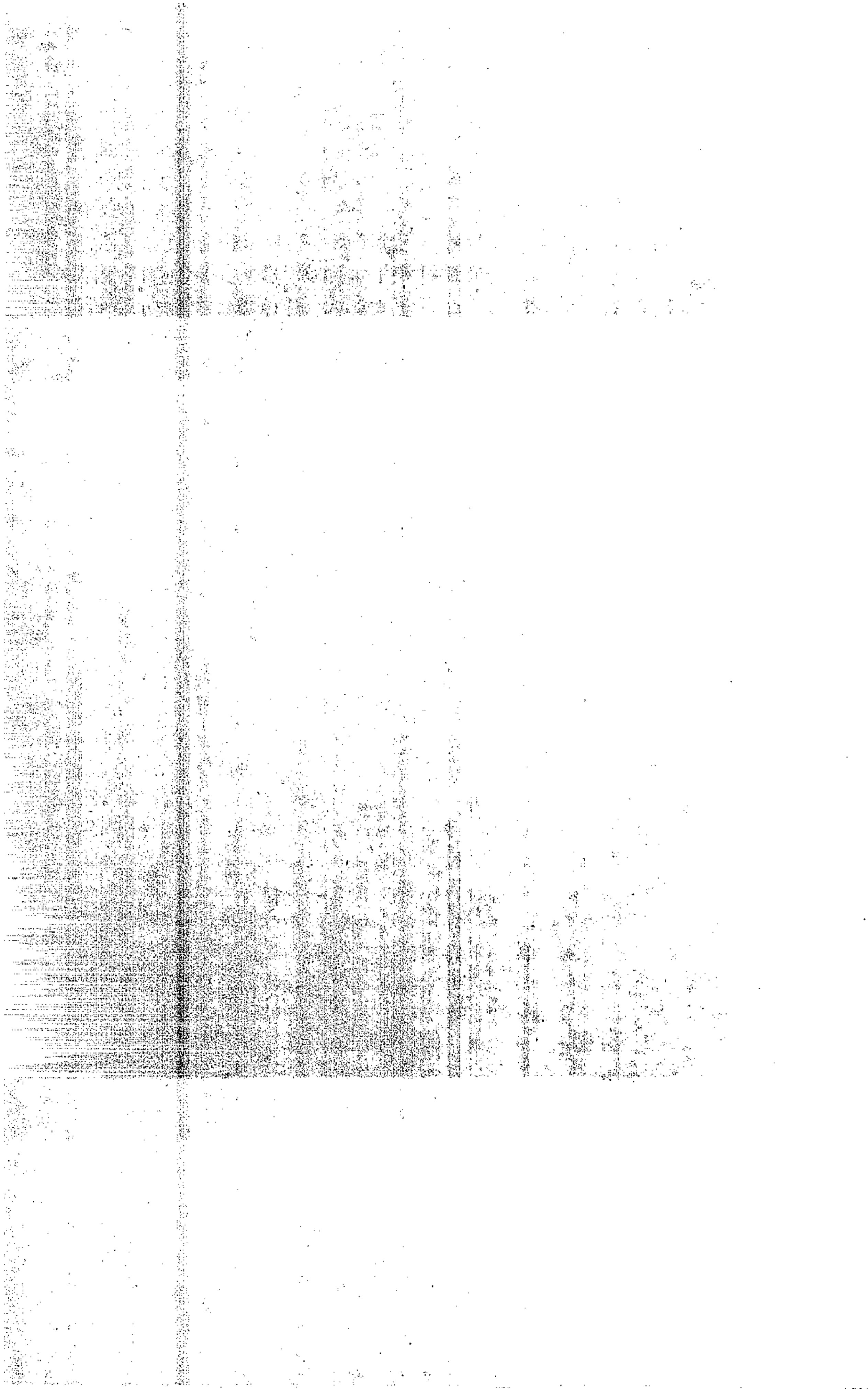
Data collected from the troughs consisted of rainfall since last sampling, sediment yield and runoff quantity for the period January 15 to May 27, 1980. There were 26 sample periods. The runoff quantity from eleven of the twenty-six sample periods were missing. There were no data for these periods because the troughs used to collect the runoff were too small. Large amounts of rainfall are common to the north coast area. The troughs overflowed during these large storm periods.

ANALYSIS

The statistical analysis of the data was aided by the use of the TENET Computer System (now obsolete and replaced by VM-360). A regression program "5;LSTAT;CURFIT" was used to fit curves and evaluate correlations obtained from the data.

After the data were fit to curves, the plotting program "452;SLIB;REGPLOT" was used to plot the data points and then draw various curves through the data. See Appendix C.

Early in the study, the curve fitting was done on an H.P. 65 hand calculator and curves were plotted by hand.



RESULTS

The data were analyzed to determine if the addition of runoff quantities could improve the current sediment collection trough method of estimating erosion.

First, the data were analyzed by the current method. Cumulative Rainfall vs. cumulative Sediment Yield were computed and plotted. A good linear correlation existed as is shown by plots 1 and 3 from trough 1, and by plots 1 and 3 from trough 2 (see Appendix D). The results from troughs 1 and 2 are virtually identical so only the results of trough 2 will be discussed, but similar results for trough 1 exist. From the plots of cumulative Rainfall vs. cumulative Sediment Yield, an average annual erosion figure can be calculated using the average annual rainfall for the area and reading the Sediment Yield from the graph at that point on the curve.

The next step was to investigate the relationship between runoff and rainfall and sediment yield in order to develop a method of incorporating runoff into an erosion estimate. The first indication of trouble occurred when the cumulative Rainfall vs. cumulative Sediment Yield curve for all data (Plot 1) was compared to the plot in which only runoff data were used, (Plot 3). There was a significant difference between the plots. The plots show that the curve which included runoff data indicates that less erosion has occurred. This makes sense, because the high intensity storms, which cause the most erosion, occurred in those cases in which the troughs overflowed. Consequently, much of the sediment was washed out of the troughs during these storm periods. This means that the data points for which there is no runoff data cannot be ignored.

An attempt to generate the missing runoff data points was made by correlating runoff vs. rainfall and runoff vs. sediment yield. This attempt failed due to the lack of large rainfall occurrence data. All of the complete data points came from small rainfall occurrences. When small occurrence data was used to generate large rainfall runoff quantities, the results were not realistic.

At this point it became obvious that another data base was needed. Professor Caruccio of the University of South Carolina was contacted in an attempt to obtain another data base, but he could not provide one. At this point, the study was terminated.

TABLE I

List of Plots (See APPENDIX D)

Plot	TROUGH 1	
1	ΣRainfall vs. ΣSediment	All Data
2	Rainfall vs. Sediment	Only Runoff Data
3	ΣRainfall vs. ΣSediment	" " "
4	Runoff vs. Sediment	" " "
5	ΣRunoff vs. ΣSediment	" " "
6	Rainfall vs. Runoff	" " "
7	ΣRainfall vs. ΣRunoff	" " "

Plot	TROUGH 2	
1	ΣRainfall vs. ΣSediment	All data
2	Rainfall vs. Sediment	Only Runoff Data
3	ΣRainfall vs. ΣSediment	" " "
4	Rainfall vs. Sediment	All Data
5	Runoff vs. Sediment	Only Runoff Data
6	ΣRunoff vs. ΣSediment	" " "
7	Rainfall vs. Runoff	" " "
8	ΣRainfall vs. ΣRunoff	" " "

REFERENCES

1. "Methods of Measuring Erosion From Road Slopes", Howell, R.B., Shirley, E.C., California Department of Transportation, TransLab, CA-DOT-TL-7108-6-76-17, January 1976.

2. "Erosion Measurements for Road Slopes", Volume III, Water Quality Manual, Federal Highway Administration, October 1976.

3. "Erosion Measurements During and After Construction (Highway 299E, Redding)", Ed Webb, Robert Carney, and Richard Howell, California Department of Transportation, CA-TL-7108-78-11 March 1978.

4. "A Comparison of Highway Slope Erosion Estimates by the Mechanical Slope Template, Sediment Collection Trough and Slope Erosion Transect Survey Methods", Richard B. Howell and James A. Racin, California Department of Transportation, CA-TL-78-20, August 1978.

5. "Erosion Measurements on a Smooth and Stepped Highway Slope (District 11)", M. Wagner, J. Egan, G.F. Warn, R. B. Howell, California Department of Transportation, CA-TL-79-15, May 1979.

6. "Evaluation of 1978 Rehabilitation Sites and Erosion Control Techniques in Redwood National Park", National Park Service, Redwood National Park, April 1980.

7. "Evaluation of Selective Erosion Control Techniques", Professor Frank Caruccio (803-777-6878), University of South Carolina, Department of Geology, 1980.

8. "Erosion Control During Highway Construction", NCHRP Report 220, Transportation Research Board, April 1980.

9. "Erosion Control During Highway Construction (Manual on Principles and Practices)", NCHRP Report 221, Transportation Research Board, April 1980.

APPENDICES

APPENDIX A

STUDY PLAN

TITLE:

"Analysis of Sediment Collection Trough Procedure Incorporating Runoff Data"

PROPOSAL

This is a 6-month project assignment for Richard Jorgensen Junior Civil Engineer, assigned to the TransLab Water Quality Section, Erosion and Physical Investigations Unit (July-December 1980.

PROBLEM

As part of the water quality analysis of an environmental impact assessment, it is necessary to identify and quanify potential sources of erosion associated with a highway project. Currently there are four basic methods of estimating erosion rates for Caltrans projects: 1) the Universal Soil Loss Equation, 2) slope erosion transect survey, 3) sediment collection trough, and 4) field estimates. These methods yield varying degrees of information ranging from very subjective data to more quantified data. The method selected for use on a proposed project depends on the level of estimated impact and whether the project is merely a planning study or a project design.

The sediment trough collection method is perhaps the most quantifiable method of the four. The Caltrans method involves measuring rainfall and collecting sediment. The US National Park Service and others have included the amount of water run-off in their analysis. It is possible that by adding runoff quantity to the sediment collection trough method, the accuracy of predicting erosion rates may be increased.

OBJECTIVE

This study will investigate the correlation of runoff, rain-fall, and sediment yield, in an attempt to obtain a more accurate method of using the sediment collection trough method to estimate erosion rates.

BACKGROUND

Sediment collection troughs were developed in 1971 by the Transportation Laboratory Water Quality Section to measure erosion from experimental plots. It was developed into a standard method for measuring erosion rates by the Districts for environmental studies in 1976. This method correlates rainfall with sediment yield data for the test plot and uses the resulting curve to predict erosion rates for an average annual rainfall. Recent studies of erosion control techniques by the National Park Service for the Redwood National Park and the University of South Carolina, Department of Geology, have utilized the sediment trough collection method of estimating erosion from their test plots. In their testing they retained and measured runoff from their test plots. The inclusion of runoff quantity into the correlation of rainfall and sediment yield has been suggested as a method of improving the accuracy of erosion estimates since soil saturation tends to increase water runoff and thus sediment transport from the slope. Data from the control plots of the National Park Service will be used to analyze correlations between runoff, rainfall, and sediment yield.

WORK PLAN

The study will be based on the analysis of data obtained from Bill Weaver (National Park Service) and possibly from the University of South Carolina. The data will first be analyzed conventionally by correlating rainfall and sediment yield. A procedure for incorporating runoff into the erosion prediction method will be determined. The procedure will be derived from curves obtained by plotting sediment yield versus runoff. The resulting curves will be used to analyze the data. The results of the two methods will be compared.

If the runoff data proves to be an important factor for increasing the accuracy of erosion prediction, plans for further study will be recommended. A report will be prepared and an oral presentation will be presented at the conclusion of the study.

References

1. "Slope Erosion Transects, Lake Tahoe Basin", Howell, R.B., Shirley, E.C., Skog, J.B., California Department of Transportation, TransLab, M&R-657078-1, July 1971.

2. "Methods of Measuring Erosion From Road Slopes", Howell, R.B., Shirley, E.C., California Department of Transportation, TransLab CA-DOT-TL-7108-6-76-17, January 1976.

3. "Erosion Measurements for Road Slopes", Volume III, Water Quality Manual, Federal Highway Administration, October 1976.

4. "Evaluation of 1978 Rehabilitation Sites and Erosion Control Techniques in Redwood National Park", National Park Service, Redwood National Park, April 1980.

5. "Evaluation of Selective Erosion Control Techniques", Buxton, H., Caruccio, F.T., University of South Carolina, December 1979.

SCHEDULE

	1980 J	A	S	O	N	D
Orientation & Literature Review	X	X				
Develop Analysis Procedure		X	X	X		
Analyze Data		X	X	X		
Write Report				X	X	X
Presentation						X

APPENDIX B

DATA

TROUGH #1

DATE	RAIN(in)	SEDIMENT(lb)	RUNOFF(in)
1-15	8.86	12.7	Overflow
1-17	1.08	0.8	Overflow
2-4	2.43	5.0	Overflow
2-6	0.53	0.3	0.30
2-19	4.75	8.3	Overflow
2-20	1.03	1.1	Overflow
2-21	0.56	0.3	0.41
2-22	0.50	0.8	0.34
2-26	1.60	0.9	0.33
2-28	2.68	1.3	Overflow
3-4	0.59	0.3	0.36
3-5	1.10	0.8	Overflow
3-6	0.39	0.2	0.24
3-18	8.66	4.2	Overflow
3-21	1.25	0.7	0.85
3-28	0.44	0.5	0.15
4-5	2.41	0.6	Overflow
4-8	0.72	2.5	0.52
4-9	0.94	0.4	0.66
4-21	2.38	0.5	Overflow
5-27	2.60	0.5	1.08

BRIDGE Cr 79-2

DATE	ΣPpt(in)	Trough #1 Σ wt(lb)	R.O. (in)	ΣRO
1-15	8.86	12.66	-	
1-17	9.94	13.47	-	
2-4	12.37	18.51	-	
2-6	12.90	18.83	.30	.30
2-19	17.65	27.12	-	
2-20	18.68	28.22	-	
2-21	19.24	28.52	.41	.71
2-22	19.74	29.33	.34	1.05
2-26	21.34	30.25	.33	1.38
2-28	24.02	31.57	-	
3-4	24.61	31.90	.36	1.74
3-5	25.72	32.71	-	
3-6	26.11	32.90	.24	1.98
3-18	34.77	37.10	-	
3-21	36.02	37.81	.85	2.83
3-28	36.46	38.31	.15	2.98
4-5	38.87	38.96	-	
4-8	39.59	41.46	.52	3.50
4-9	40.53	41.89	.66	4.16
4-21	42.91	42.35	-	
5-27	45.51	42.80	1.08	5.24

BRIDGE CREEK

Trough #1

Omitting Samplings without R.O. Data

DATE	Rain (In)	Σppt	Wt(g)	Σwt(g)	R.O.(in)	ΣR.O.
2-6	.53	.53	143.8	143.8	.30	.30
2-21	.56	1.09	135.1	278.9	.41	.71
2-22	.50	1.59	369.4	648.3	.34	1.05
2-26	1.60	3.19	418.4	1066.7	.33	1.38
3-4	.59	3.78	148.9	1215.6	.36	1.74
3-6	.39	4.17	88.6	1304.2	.24	1.98
3-21	1.25	5.42	323.4	1627.6	.85	2.83
3-28	.44	5.86	227.1	1854.7	.15	2.98
4-8	.72	6.58	1135.0	2989.7	.52	3.50
4-21	.94	7.52	199.3	3189.0	.66	4.16
5-27	2.60	10.12	207.4	3396.4	1.08	5.24

Bridge Creek

Trough #1

Omitting samplings without R.O. Data

	wt (lb)	Σ wt (lb)	
2-6	.32	.32 ✓	1
2-21	.30	.62 ✓	
2-22	.81	1.43 ✓	3
2-26	.92	2.35 ✓	
3-4	.33	2.68 ✓	5
3-6	.20	2.88 ✓	
3-21	.71	3.59 ✓	7
3-28	.50	4.09 ✓	
4-8	2.50	6.59 ✓	9
4-9	.44	7.03 ✓	
7	.46	7.49	11

21

Trough #1

Σ Rainfall vrs Σ Sediment **RAIN SED1**

	Σ Pre (in)	Σ Sed (grams)	lbs
2-6	.53	143.8	.32
2-21	1.09	278.9	.61
2-22	1.59	648.3	1.43
2-26	3.19	1066.7	2.35
3-4	3.78	1215.6	2.68
3-6	4.17	1304.2	2.88
3-21	5.42	1627.6	3.59
3-28	5.86	1854.7	4.09
4-8	6.58	2989.7	6.59
4-9	7.52	3189.0	7.03
5-27	10.12	3396.4	7.49

Curves 1, 3, 6

Changed to lbs

Trough #1

Σ Rainfall vrs Σ Runoff RAINR01

	Σ Rain (in)	Σ Run (in)
2-6	.53	.30
2-21	1.09	.71
2-22	1.59	1.05
2-26	3.19	1.38
3-4	3.78	1.74
3-6	4.17	1.48
3-21	5.42	2.83
3-28	5.86	2.98
4-8	6.58	3.50
4-9	7.52	4.16
5-27	10.12	5.24

1,3,6

Trough #1

Σ Runoff vrs Σ Sediment

RUN SED1

	Σ RO	Σ Sed (g)	Σ sed (lbs)
2-6	.30	~~143.8~~	.32
2-21	.71	~~228.9~~	.61
2-22	1.05	~~648.3~~	1.43
2-26	1.38	~~1066.7~~	2.35
3-4	1.74	~~1215.6~~	2.68
3-6	1.98	~~1304.2~~	2.88
3-21	2.83	~~1622.6~~	3.59
3-28	2.98	~~1854.7~~	4.09
4-8	3.50	~~2989.7~~	6.59
4-9	4.16	~~3189.0~~	7.03
5-27	5.24	~~3396.4~~	7.49

1, 3, 6 Changed.

Trough #1

Rainfall vrs Sediment

	Rain	Sed (grams)	Rain Sed (lbs)
2-6	.53	43.8	.32
2-21	.56	135.1	.61
2-22	.50	369.4	1.43
2-26	1.60	418.4	2.35
3-4	.59	148.9	2.68
3-6	.39	88.6	2.88
3-21	1.25	323.4	3.59
3-28	.44	227.1	4.09
4-8	.72	1135.0	6.59
4-9	94	149.3	7.03
5-27	2.60	207.4	7.49

maybe 6

Trough #1

Rainfall vrs Runoff RAIN RO

	Rain	Run	
2-6	.53	.30	
2-21	.56	.41	
2-22	.50	.34	
2-26	1.60	.33	Remove this Maybe
3-4	.59	.36	1) .84
3-6	.39	.24	4) .93
3-21	1.25	.85	
3-28	.44	.15	
4-8	.72	.52	
4-9	.94	.66	
5-27	2.60	1.08	Remove this also

Trough #1

Runoff Vrs Sediment

RUN SED

	RO	Sed (g)	Sed (lb)
2-6	.30	143.8	.32
2-21	.41	135.1	.61
2-22	.34	369.4	1.43
2-26	.33	418.4	2.35
3-4	.36	148.9	2.68
3-6	.24	88.6	2.88
3-21	.85	323.4	3.59
3-28	.15	227.1	4.09
4-8	.52	1135.0	6.59
4-9	.66	199.3	7.03
5-27	1.08	207.4	7.49

Trough #2

Date	Rain (in)	Sediment (lb)	Runoff (in)
1-15	8.86	13.38	Overflow
1-17	1.08	0.87	Overflow
2-4	2.43	4.10	Overflow
2-6	0.53	0.22	0.28
2-19	4.75	5.62	overflow
2-20	1.03	0.58	Overflow
2-21	0.56	0.15	0.37
2-22	0.50	0.41	0.25
2-26	1.60	0.65	0.29
2-28	2.68	0.38	overflow
3-4	0.59	0.31	0.31
3-5	1.11	0.85	overflow
3-6	0.39	0.94	0.24
3-18	8.66	4.55	Overflow
3-21	1.25	0.55	0.81
3-28	0.44	0.09	0.15
4-5	2.41	0.82	Overflow
4-8	0.72	1.92	0.42
4-9	0.94	0.40	0.61
4-21	2.38	0.48	1.03
5-27	2.60	0.50	0.76

Bridge Cr 79-2
Trough #2

	Σ Rain (in)	Σ wt (lb)		RO (in)
1-15	8.86	13.38		–
1-17	9.94	14.25		–
2-4	12.37	18.34		–
2-6	12.90	18.57		.28
2-19	17.65	24.18	5	–
2-20	18.68	24.76		–
2-21	19.24	24.91	7	.37
2-22	19.74	25.32		.25
2-26	21.34	25.97	9	.29
2-28	24.02	26.35		–
3	24.61	26.66	11	.31
3-5	25.72	27.52		–
3-6	26.11	28.45	13	.24
3-18	34.77	33.00		–
3-21	36.07	33.55	15	.81
3-28	36.46	33.64		.15
4-5	38.87	34.46	17	–
4-8	39.59	36.38		.42
4-9	40.53	36.78	19	.61
4-21	42.91	37.26		1.03
5-27	45.51	37.77	21	.76

Bridge Creek 79-2
Sediment Trough #2

	(g)	(lb)	(g)	(lb)
1-15	6069.2 =	13.38	6069.2 =	13.38
1-17	393.6 =	.87	6462.8 =	14.25
2-4	1857.7 =	4.10	8320.5 =	18.34
2-6	100.7 =	.22	8421.2 =	18.57
2-19	2548.5 =	5.62	10,969.7 =	24.18
2-20	262.5 =	.58	11,232.2 =	24.76
2-21	67.4	.15	11,299.6 =	24.91
2-22	186.0 =	.41	11,485.6 =	25.32
2-26	293.9 =	.65	11,779.5 =	25.97
2-28	173.4	.38	11,952.9 =	26.35
3-	142.1 =	.31	12,095.0 =	26.66
3-5	385.9 =	.85	12,480.9 =	27.52
3-6	425.1 =	.94	12,906.0 =	28.45
3-18	2062.0 =	4.55	14,968.0 =	33.00
3-21	248.5 =	.55	15,216.5 =	33.55
3-28	42.2 =	.09	15,258.7 =	33.64
4-5	370.6 =	.82	15,629.3 =	34.46
4-8	872.5 =	1.92	16,501.8 =	36.38
4-9	181.0 =	.40	16,682.8 =	36.78
4-21	217.4 =	.48	16,900.2 =	37.26
5-27	230.9 =	.50	17,131.1 =	37.77

30

Bridge Creek

Trough # 2

Omitting Sampling without R.O. Data

	Rain(in.)	Σ ppt	wt.	Σ wt	R.O. (in)	Σ R.O
2-6	.53	.53	.22	.22	.28	.28
2-21	.56	1.09	.15	.37	.37	.65
2-22	.50	1.59	.41	.78	.25	.90
2-26	1.60	3.19	.65	1.43	.29	1.19
3-4	.59	3.78	.31	1.74	.31	1.50
3-6	.39	4.17	.94	2.68	.24	1.74
3-21	1.25	5.42	.55	3.23	.81	2.55
3-28	.44	5.86	.09	3.32	.15	2.70
4-8	.72	6.58	1.92	5.24	.42	3.12
4-9	.94	7.52	.40	5.64	.61	3.73
4-21	2.38	9.90	.48	6.12	1.03	4.76
5-27	2.60	12.50	.50	6.62	.76	5.52

①

Trough # 2

Σ Rainfall vrs Σ Sediment PRECSED2

	Rain	Sed
2-6	.53	.22
2-21	1.09	.37
2-22	1.59	.78
2-26	3.19	1.43
3-4	3.78	1.74
3-6	4.17	2.68
3-21	5.42	3.23
3-28	5.86	3.32
4-8	6.58	5.24
4-9	7.52	5.64
4-21	9.90	6.12
5-27	12.50	6.60

111

Trough #2

Σ Rainfall vrs Σ Runoff **PRECRO2**

	Rain	Runoff
2-6	.53	.28
2-21	1.09	.65
2-22	1.59	.90
2-26	3.19	1.19
3-1	3.78	1.50
3-6	4.17	1.74
3-21	5.42	2.55
3-28	5.86	2.70
4-8	6.58	3.12
4-9	7.52	3.74
4-21	9.90	4.76
5-27	12.50	5.52

Trough #2

Σ Runoff vrs Σ Sediment ROSED2

	Runoff	Sed
2-6	.28	.22
2-21	.65	.37
2-22	.90	.78
2-26	1.19	1.43
3-4	1.50	1.74
3-6	1.74	2.68
3-21	2.55	3.23
3-28	2.70	3.32
4-8	3.12	5.24
4-9	3.73	5.64
4-21	4.76	6.12
5-27	5.52	6.62

Trough #2

Rainfall vrs Sediment PRECSED

	Rain	Sed
2-6	.53	.22
2-21	.56	.15
2-22	.50	.41
2-26	1.60	.65
3-4	.59	.31
3-6	.39	.94
3-21	1.25	.55
3-28	.44	.09
4-8	.72	1.92
4-9	.94	.40
4-21	2.38	.48
5-27	2.60	.50

Trough #2

Rainfall vrs Runoff

PRECRO

	Rain	Run
2-6	.53	.28
2-21	.56	.37
2-22	.50	.25
2-26	1.60	.29
3-4	.59	.31
3-6	.39	.24
3-21	1.25	.81
3-28	.44	.15
4-8	.72	.42
4-9	.94	.61
4-21	2.38	1.03
5-27	2.60	.76

Trough #2 ⑥

Runoff vrs Sediment ROSED

	Run	Sed
2-6	.28	.22
2-21	.37	.15
2-22	.25	.41
2-26	.29	.65
3-4	.31	.31
3-6	.24	.94
3-21	.81	.55
3-28	.15	.09
4-8	.42	1.92
4-9	.61	.40
4-21	1.03	.48
5-27	.76	.50

APPENDIX C

PROGRAMS

Regression Program

```
TENET 210 TIME-SHARING SYSTEM  1508  08/20/80 35
-LOGIN
        452;SWATER
PASSWORD?
ERROR
PASSWORD?
-

 COPY TEL TO AUG18
10 30 15 35 25 50
20 450 55 66 33 55
-

 COPY AUG18 TO TEL
1 10 30 15 35 25 50
2 20 450 55 66 33 55
-

 COPY TEL OVER AUG18
TITLE,10
10 20 13 40 29 33 44 50
30 44 55 99 22 59 22 33
 DI
@

 LOAD 'AUG18'
   3  RECORDS AFFECTED
-
```

39

```
 LISTY

SYNTAX ERROR
LISTY
LIST
    1.00 TITLE,10
    2.00 10 20 13 40 29 33 44 50
    3.00 30 44 55 99 22 59 22 33
@


 ALTER 1
    1.00 TITLE,10
    1.00 TITLE,8
@SAVE OLD 'AUG18';

SYNTAX ERROR
SAVE OLD 'AUG18';
SAVE OLD 'AUG18'
    3  RECORDS AFFECTED
@Q CLEAR
-LOGO
 1515  08/20/80
CPU MINS -  0.015
TERMINAL MINS -    6.08
FILE MODULES - 16
----------------



   TENET 210 TIME-SHARING SYSTEM  1515  08/20/80 35

-LOGIN  452;SWATER
PASSWORD?
-BASI
>

 RUN '5;LSTAT;CURFIT'
```

Regression Program

```
   ****5;LSTAT;CURFIT*** MODIFIED JULY 1978***

      DATA FILENAME OR 'EXP' FOR PROGRAM EXPLANATION??EXP

            ***** PROGRAM 5;LSTAT;CURFIT *****

         THIS PROGRAM PERFORMS A LEAST-SQUARES CURVE FIT TO THE
      LINEAR EQUIVALENTS OF THE FOLLOWING SIX FUNCTIONS:

      CURVE                  TYPE            LINEAR EQUIVALENT

      Y=A+B*X             LINEAR
      Y=A*EXP(B*X)        EXPONENTIAL       LOG(Y)=LOG(A)+B*X
      Y=A*X^B             POWER             LOG(Y)=LOG(A)+B*LOG(X)
      Y=A+B/X             HYPERBOLIC        Y=A+B/X
      Y=1/(A+B*X)         HYPERBOLIC        1/Y=A+B*X
      Y=X/(A+B*X)         HYPERPOLIC        1/Y=B+A/X
```

A MAXIMUM OF 1000 DATA PAIRS MAY BE ENTERED FOR EACH PROBLEM AND MORE THAN ONE PROBLEM MAY BE IN A DATA FILE.

THE DATA IS READ FROM A SEQUENTIAL TEXT DATA FILE IN THE FOLLOWING FORMAT FOR EACH PROBLEM:

```
TIT$,N
X(1),Y(1),X(2),Y(2),...,X(N),Y(N)
```

WHERE:

```
TIT$ = JOB TITLE
   N = NUMBER OF POINTS
X(I) = INDEPENDENT VARIABLE
Y(I) = DEPENDENT VARIABLE
```

UPON LINKING THIS PROGRAM AND ENTERING THE DATA FILE NAME, THE CURVE TYPE AND COEFFICIENTS WILL BE PRINTED WITH THE FOLLOWING STATISTICS ON THE LINEAR FORM OF THE CURVE:

RSQ - COEFFICIENT OF DETERMINATION
THIS IS THE FRACTIONAL PORTION OF THE DEPENDENT VARIABLE EXPLAINED BY REGRESSION. THE SQUARE ROOT OF THIS STATISTIC TIMES THE SIGN OF THE SLOPE (B COEFFICIENT) IS THE COEFFICIENT OF CORRELATION

F - F-RATIO OF REGRESSION/RESIDUAL MEAN SQUARES
TEST OF SIGNIFICANCE OF REGRESSION USING 1/(N-2) DEFREES OF FREEDOM.

SYX - STANDARD ERROR OF THE ESTIMATE OF Y
THIS STATISTIC IS USUALLY OF INTEREST IN LINEAR ANALYSES ONLY

AT THIS POINT, THE USER WILL BE ASKED TO ENTER A NUMBER FOR THE CURVE TYPE HE WISHES TO HAVE RESULTS LISTED. IF A '0' IS ENTERED, THE PROGRAM WILL GO TO THE NEXT PROBLEM IN THE DATA FILE OR END.
IF A NUMBER FROM 1 TO 6 IS ENTERED, A LIST OF X-ACTUAL Y-ACTUAL,Y-CALCULATED AND RESIDUALS WILL BE PRINTED.

```
>RUN

 ****5;LSTAT;CURFIT*** MODIFIED JULY 1978***

   DATA FILENAME OR 'EXP' FOR PROGRAM EXPLANATION?AUG18

   DO YOU WANT TO SET TOP-OF-FORM FOR PAGING? YES OR NO  ?NO
```

LEAST-SQUARES CURVE FIT

TITLE

CURVE TYPE	A	B	BASED ON LINEAR TRANSFORM RSQ	F	SYX
1. Y=A+B*X	11.724373	1.263133	.6369	10.52	15.627643
2. Y=A*EXP(B*X)	21.546128	.024377	.6177	9.69	.314259
3. Y=A*X^B	5.661560	.631672	.5906	8.65	.325202
4. Y=A+B/X	72.991231	-546.875122	.4055	4.09	19.995432
5. Y=1/(A+B*X)	.041661	-.000568	.5234	6.59	.008889
6. Y=X/(A+B*X)	.337024	.009809	.6250	10.00	.007885

```
LIST VALUES FOR CURVE TYPE (1-6 OR 0 TO STOP)?NO

ILLEGAL INPUT DELIMITOR
??0

>QUIT
-LOGO
 1522  08/20/80
CPU MINS -  0.083
TERMINAL MINS -   6.09
FILE MODULES - 16
```

Plotting Program

```
SAVE 'TRIAX WBAZ!

>SAVE 'TRIAX WBASIC A1'
READY
>BYE
R;

>LOGO
CONNECT= 01:02:08 VIRTCPU= 000:46.10 TOTCPU= 000:50.02
LOGOFF AT 08:56:59 PDT WEDNESDAY 08/27/80

   TENET 210 TIME-SHARING SYSTEM  1006  08/27/80 35

=LOGIN 452;SWATER
PASSWORD?
=BASI
>RUN '452;SLIB;REGPLOT'
        DO YOU WANT THE PROGRAM EXPLANATION ? ?
```

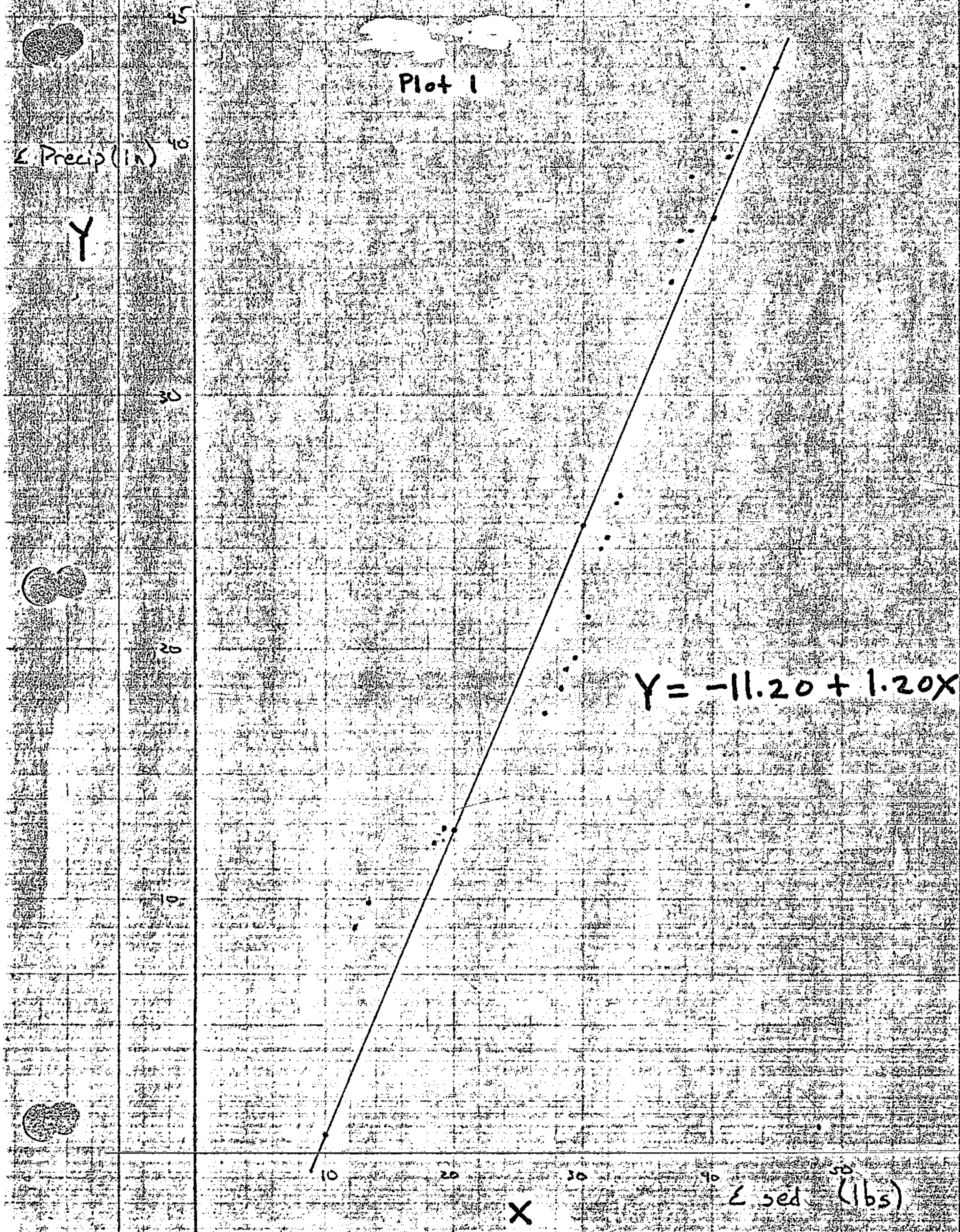
```
                                        YES

REGPLOT** PLOTS UP TO 1000 PAIRS ON HP
PLOTTER. DATA MAY BE EITHER IN XY OR ALL X THEN ALL Y.
IF DESIRED A BEST-FIT FUNCTION FROM CURFTIT MAY BE
PLOTTED THRU YOUR POINTS
USING THE A & B COMPONENTS OF ANY OF 6 BEST FIT
FORMULAS FROM 5;LSTAT;CURFIT PROGRAM...SEVERAL DATA SETS MAY
BE CONTAINED UNDER ONE FILENAME.


    1= XY PAIRS
    2= ALL X, THEN ALL Y

    WHICH ?1

    DO YOU WANT THE PLOTTER TO PRINT X  OR  +
    WHEN THERE ARE 2 POINTS, OR 3 OR MORE POINTS IN
    THE SAME LOCATION. ?
?NO
 DATA FILENAME?PRECSED2
 XMIN,XMAX,YMIN,YMAX?0,20,0,7

WHEN PLOTTER IS READY TYPE--CONTINUE

PAUSE AT LINE 540
>CONTINUE

ILLEGAL COMMAND
>CONTINUE
 NOW PLOTTING PRECSED2   12 POINTS

PLTP2085 3828
2710 4614
2930 4742
3290 7485
3760 805
 12 OF THE 12 POINTS HAVE BEEN PLOTTED


   DO YOU WANT TO DRAW A LINE THROUGH YOUR POINTS?YES

   ENTER...1 ,IF YOU ONLY WANT TO CONNECT THE POINTS
           2 ,IF YOU WANT TO PLOT ONE OF 6 FUNCTIONS FROM CURFIT
?2

   ENTER THE NUMBER OF THE CURVE TYPE
    1. Y=A+B*X
    2. Y=A*EXP(B*X)
    3. Y=A*X^B
    4. Y=A+B/X
    5. Y=1/(A+B*X)
    6. Y=X/(A+B*X)
   WHICH  ??3


   INPUT A,B  ?#

INTERRUPT DURING LINE 760
>QUIT
-LOGO
 1017  08/27/80
CPU MINS -  0.074
```

APPENDIX D

DATA PLOTS

Σ Rainfall vs Σ Sediment Trough #1 | R. Jorgensen

All data Points



46

Σ Rainfall Vs Σ sediment

Trough 1 all data pts ---

Linear Regression HP65

$a_0 = -11.20$

$a_1 = 1.20$

$r^2 = .92$

$S_{y \cdot x} = 3.35$

$S_0 = 2.66$

$S_1 = .08$

X	Y
10	.85
20	12.89
30	24.94
40	36.98
45	43.01

Drawn on graph

Equation: $-11.20 + 1.20x = y$

Rain Sed

DATA FILENAME OR 'EXP' FOR PROGRAM EXPLANATION?RAINBED

DO YOU WANT TO SET TOP-OF-FORM FOR PAGING? YES OR NO ?NO

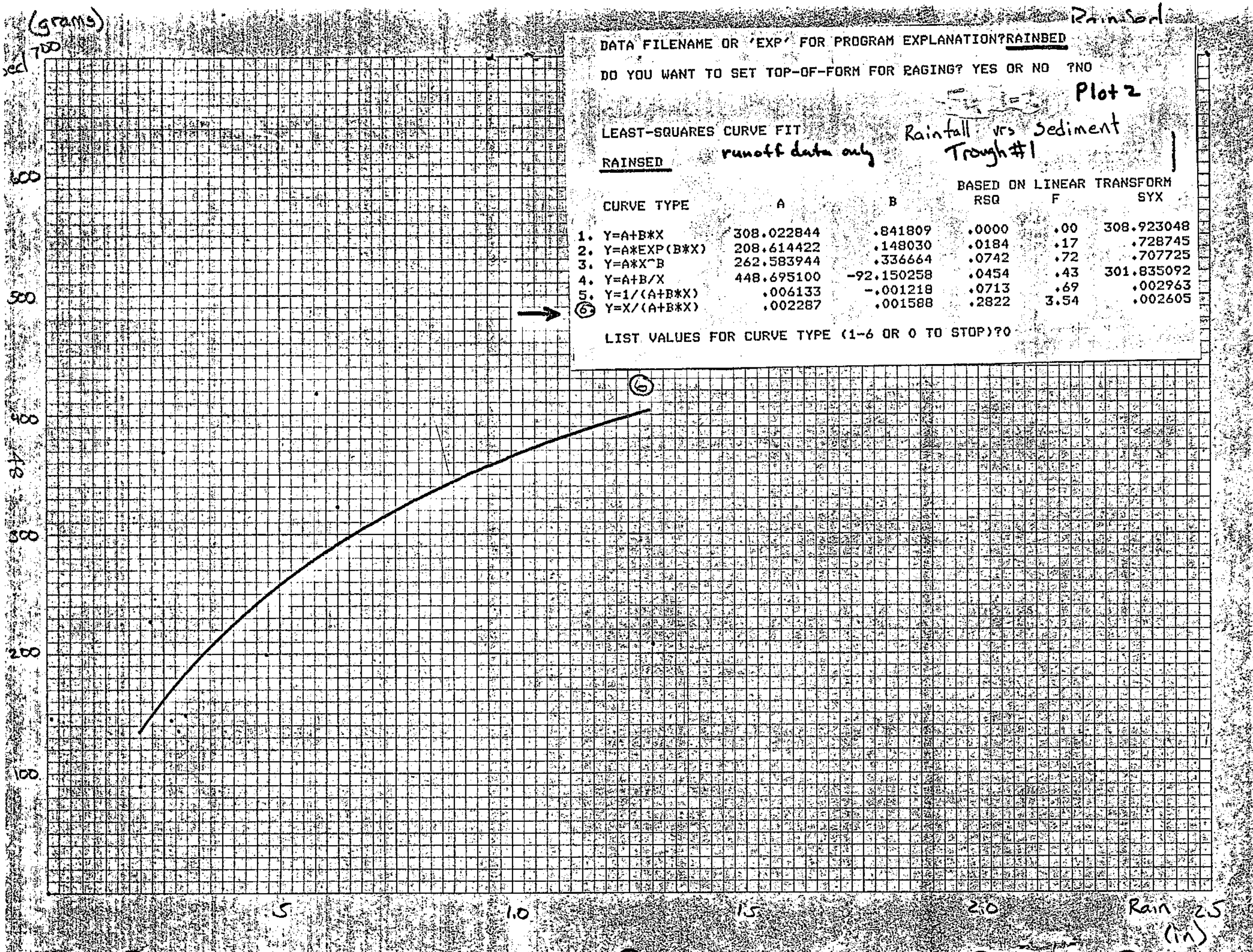
Plot 2

LEAST-SQUARES CURVE FIT Rainfall vrs Sediment

RAINSED runoff data only Trough #1

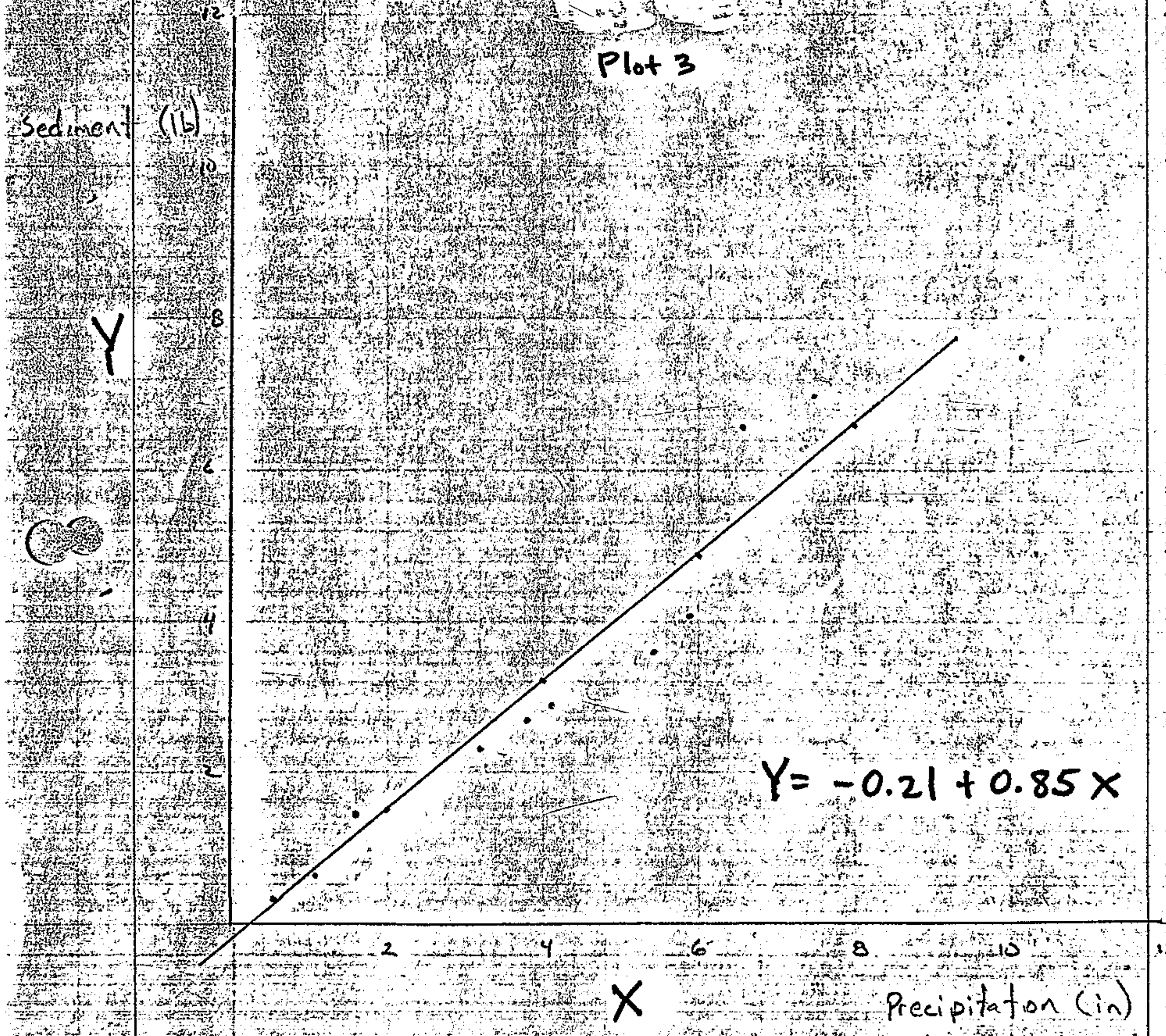
	CURVE TYPE	A	B	RSQ (BASED ON LINEAR TRANSFORM)	F	SYX
1.	Y=A+B*X	308.022844	.841809	.0000	.00	308.923048
2.	Y=A*EXP(B*X)	208.614422	.148030	.0184	.17	.728745
3.	Y=A*X^B	262.583944	.336664	.0742	.72	.707725
4.	Y=A+B/X	448.695100	-92.150258	.0454	.43	301.835092
5.	Y=1/(A+B*X)	.006133	-.001218	.0713	.69	.002963
6.	Y=X/(A+B*X)	.002287	.001588	.2822	3.54	.002605

LIST VALUES FOR CURVE TYPE (1-6 OR 0 TO STOP)?0



Σ Rainfall vcs Σ Sediment
Only points with R.O. data

Plot 3



Trough #1

Only Data with R.O. information

Σ Rainfall vrs Σ Sediment

Least squares fit regression

$y = a_0 + a_1 x$

$a_0 = -.21$

$a_1 = .85$

$r^2 = .93$

$s_{y/x} = .72$

$s_0 = .42$

$s_1 = .08$

x	y
2	1.5
4	3.2
6	4.9
8	6.6
10	8.3

Drawn on graph

Sediment = -.21 + .85 (Rainfall)

Sed (grams)

700

Runoff vrs Sediment

```
DATA FILENAME OR 'EXP' FOR PROGRAM EXPLANATION?RUNSED

DO YOU WANT TO SET TOP-OF-FORM FOR PAGING? YES OR NO  ?NO
```

Plot 4

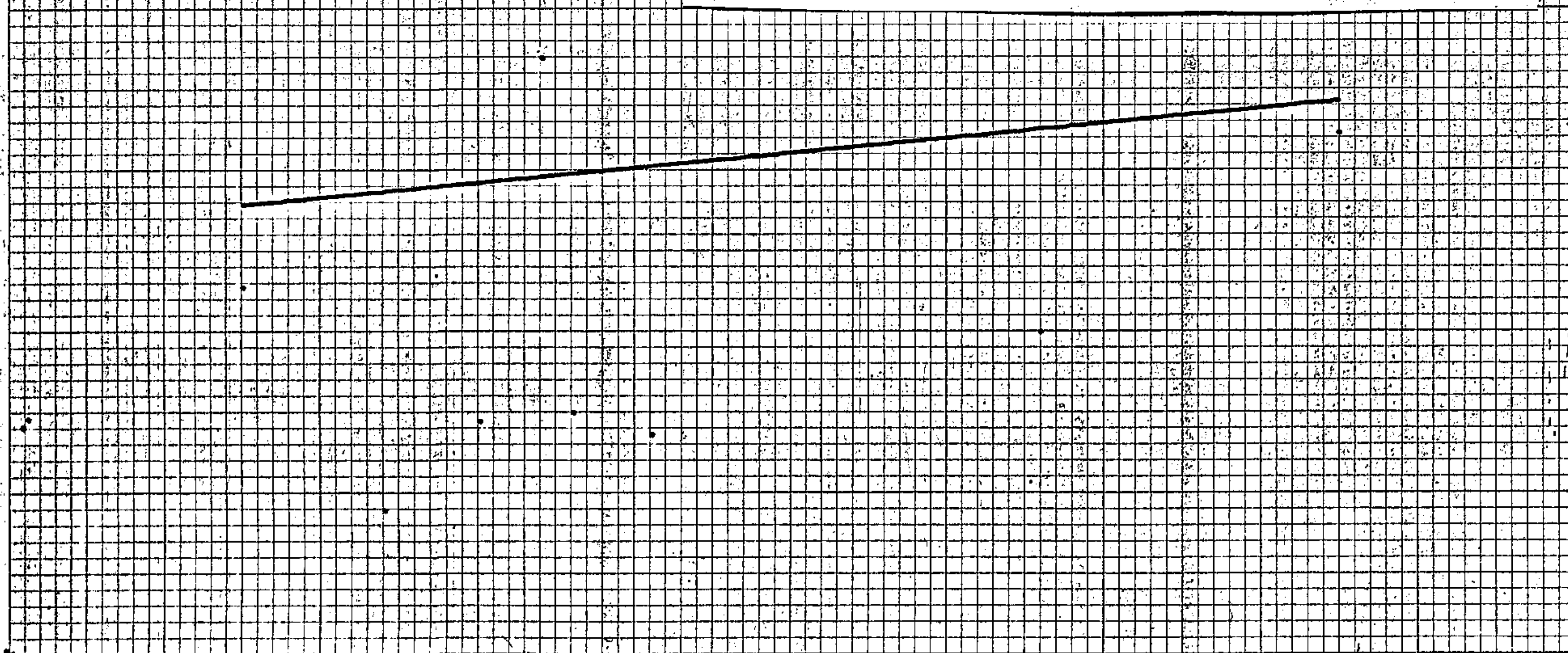
Runoff vrs Sediment trough #1

```
LEAST-SQUARES CURVE FIT

RUNSED
```

runoff data only

	CURVE TYPE	A	B	RSQ	F	SYX
				BASED ON LINEAR TRANSFORM		
1.	Y=A+B*X	264.303760	93.331801	.0080	.07	307.681872
2.	Y=A*EXP(B*X)	191.967447	.448036	.0326	.30	.723453
3.	Y=A*X^B	309.705894	.297791	.0591	.57	.713465
4.	Y=A+B/X	419.735080	-39.510058	.0470	.44	301.572419
5.	Y=1/(A+B*X)	.006444	-.002904	.0784	.77	.002952
6.	Y=X/(A+B*X)	.000484	.003703	.0711	.69	.002963

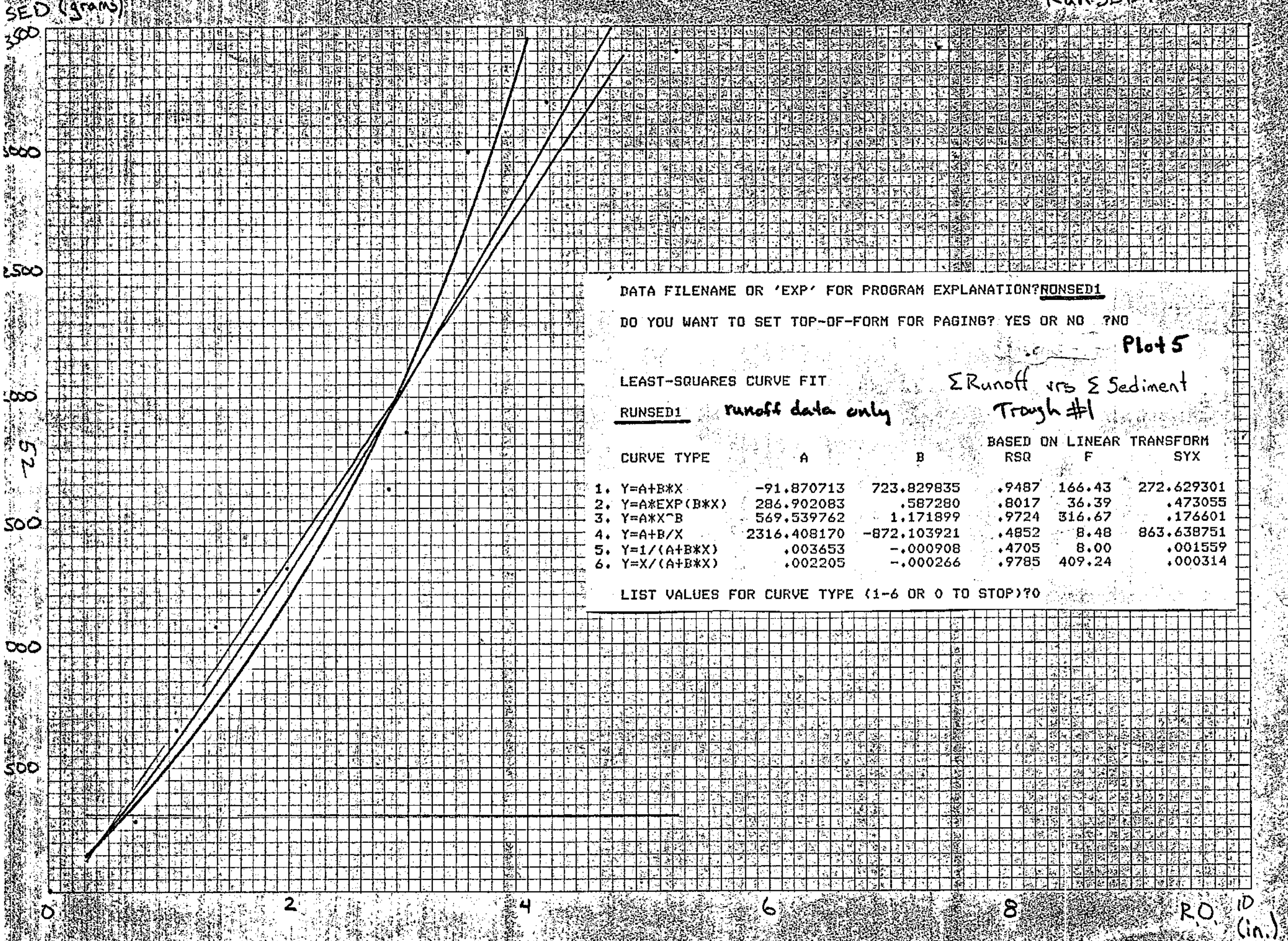
```
LIST VALUES FOR CURVE TYPE (1-6 OR 0 TO STOP)?0
```



Runoff

1.0

RunSED1



52

DATA FILENAME OR 'EXP' FOR PROGRAM EXPLANATION?RUNSED1

DO YOU WANT TO SET TOP-OF-FORM FOR PAGING? YES OR NO ?NO

Plot 5

LEAST-SQUARES CURVE FIT

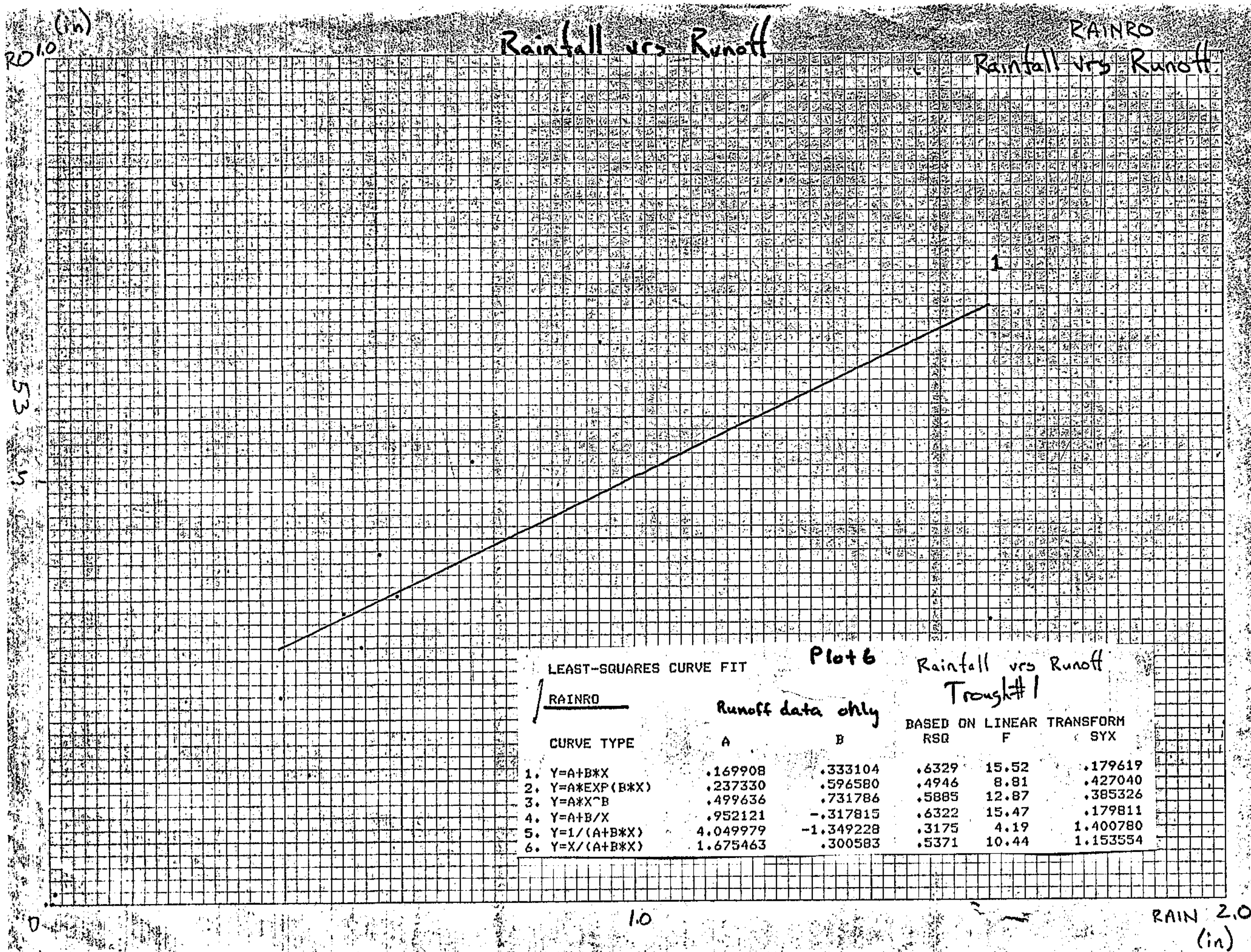
Σ Runoff vrs Σ Sediment

Trough #1

RUNSED1 runoff data only

CURVE TYPE	A	B	RSQ	F	SYX
			BASED ON LINEAR TRANSFORM		
1. Y=A+B*X	-91.870713	723.829835	.9487	166.43	272.629301
2. Y=A*EXP(B*X)	286.902083	.587280	.8017	36.39	.473055
3. Y=A*X^B	569.539762	1.171899	.9724	316.67	.176601
4. Y=A+B/X	2316.408170	-872.103921	.4852	8.48	863.638751
5. Y=1/(A+B*X)	.003653	-.000908	.4705	8.00	.001559
6. Y=X/(A+B*X)	.002205	-.000266	.9785	409.24	.000314

LIST VALUES FOR CURVE TYPE (1-6 OR 0 TO STOP)?0



Plot 6 Rainfall vrs Runoff
Trough #1

LEAST-SQUARES CURVE FIT

RAINRO

Runoff data only

BASED ON LINEAR TRANSFORM

	CURVE TYPE	A	B	RSQ	F	SYX
1.	Y=A+B*X	.169908	.333104	.6329	15.52	.179619
2.	Y=A*EXP(B*X)	.237330	.596580	.4946	8.81	.427040
3.	Y=A*X^B	.499636	.731786	.5885	12.87	.385326
4.	Y=A+B/X	.952121	-.317815	.6322	15.47	.179811
5.	Y=1/(A+B*X)	4.049979	-1.349228	.3175	4.19	1.400780
6.	Y=X/(A+B*X)	1.675463	.300583	.5371	10.44	1.153554

Trough #2

linear Regression HP-65

$a_0 = -15.84$

$a_1 = 1.53$

$r^2 = .96$

$S_{y \cdot x} = 2.37$

$S_0 = 2.05$

$S_1 = .07$

x	y
10	-.56
20	14.72
30	30
40	45.27

Drawn on graph

good fit

Equation: $-15.84 + 1.53x = y$

Rainfall vrs Sediment
Trough #2
Power curve fit (H.P.65)

$y = ax^b$

$a = .12$

$b = 1.61$

$r^2 = .97$

x	y
10	4.92
20	15.03
30	28.90
40	45.94

Good fit!

57

Rainfall vrs Sediment
Trough #2

Parabolic Curve Fit (H.P. 65)

$a_0 = 7.17$

$a_1 = -.36$

$a_2 = .04$

x	y
10	7.13
20	14.25
30	28.54
40	50

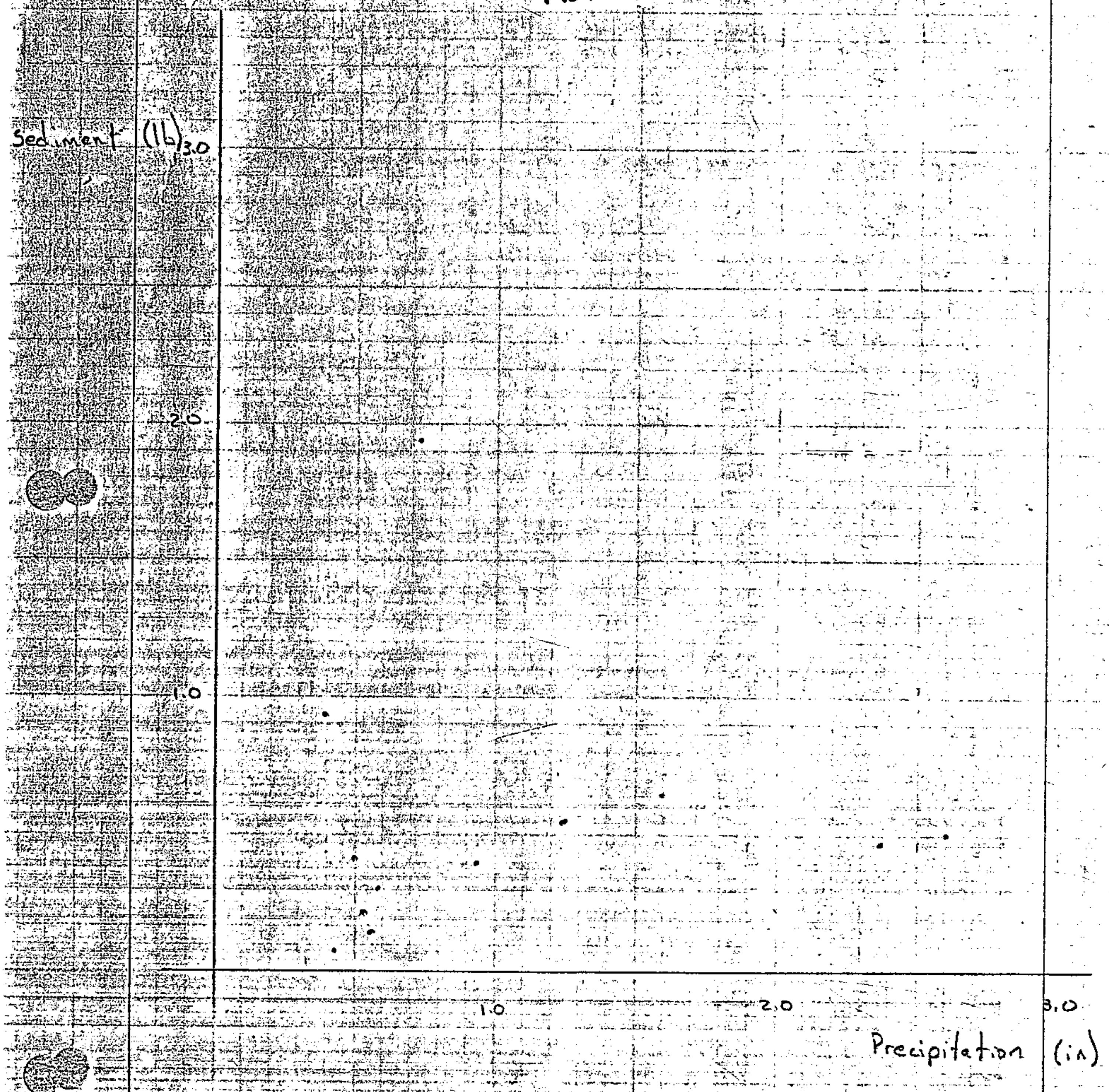
This closely approximates our data

Trough #2

Rainfall vrs Sediment

Only R.O. Data

Plot 2



Rainfall vrs Runoff
Only R.O. Data

Linear Regression

$a_0 = .55$

$a_1 = 4.2 \times 10^{-3}$ $\underline{x}$ $\underline{y}$

$r^2 = 4.35 \times 10^{-5}$

$s_{y \cdot x} = .51$

$s_0 = .26$

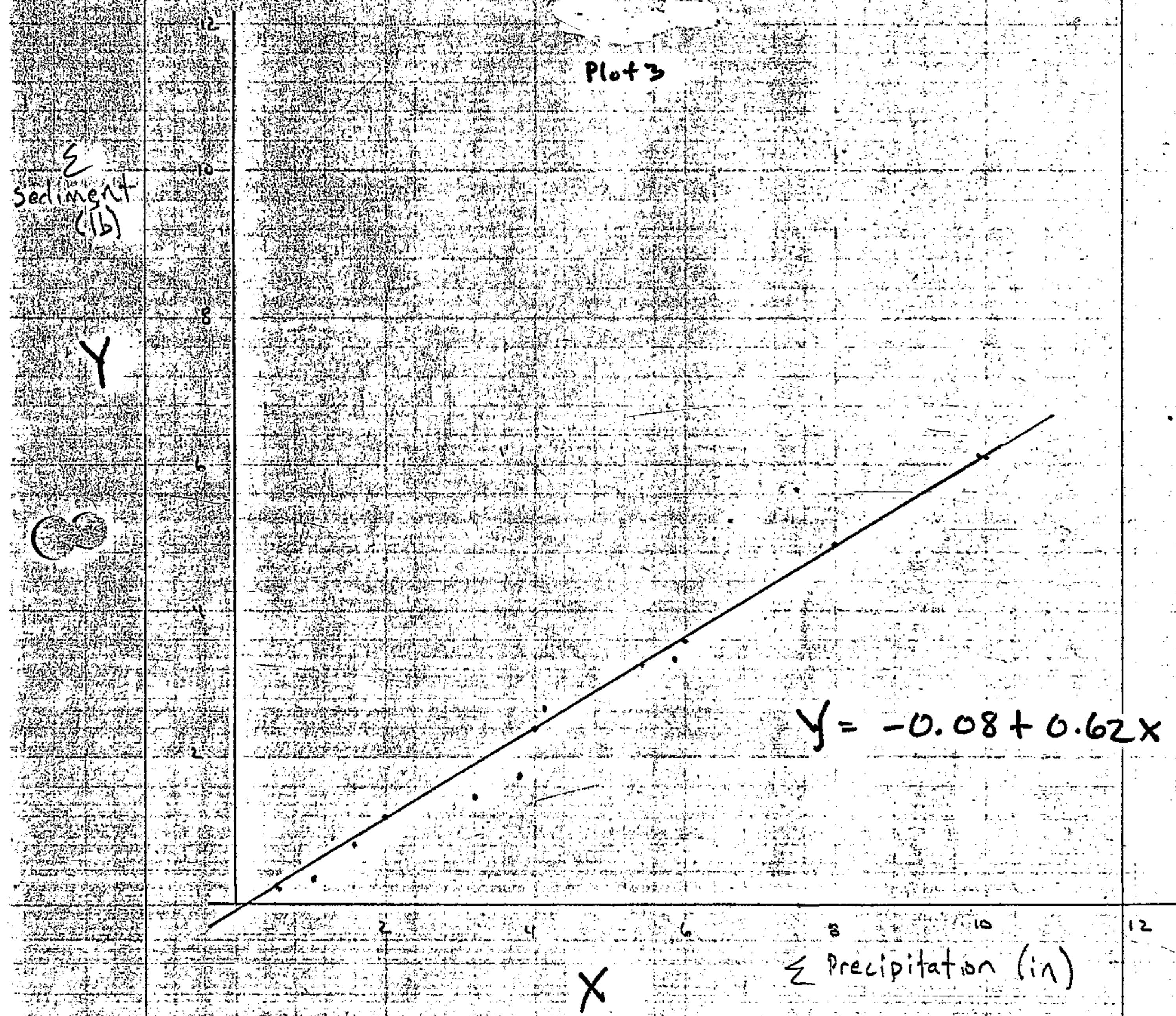
$s_1 = .20$

Sediment is a constant?

Trough #2

Σ ~~Precip~~ Rainfall Vrs Σ sediment

Only Data with R.O. Used



Trough #2

ΣPrecip vrs Σsediment

Linear Regression

$a_0 = -.08$

$a_1 = .62$

$r^2 = .92$

$S_{y.x} = .66$

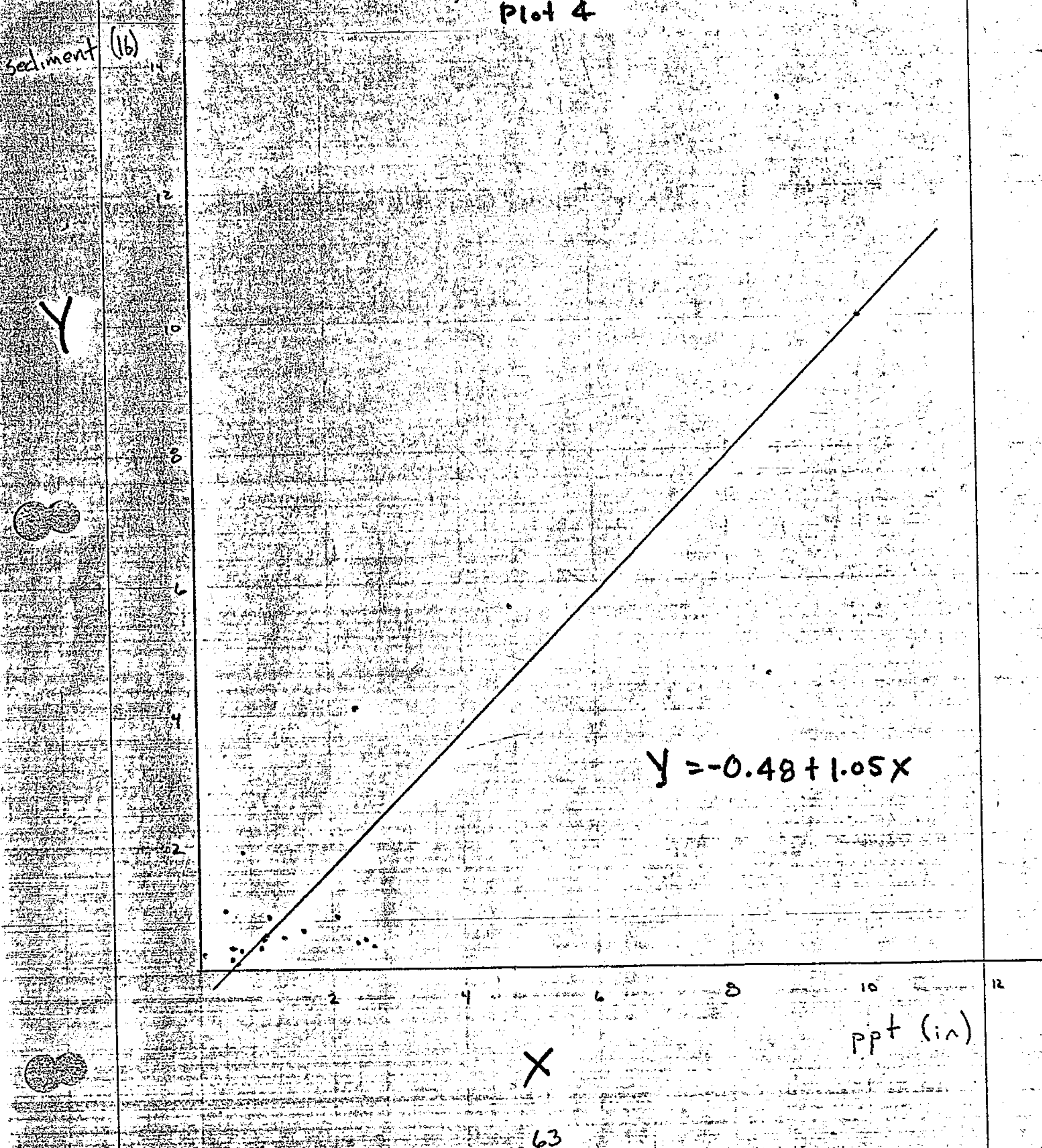
$S_0 = .35$

$S_1 = .06$

x	y
2	1.2
4	2.4
6	3.6
8	4.9
10	6.1
12	7.3

Equation $y = -.08 + .62(x)$

Rainfall vrs Sediment
All data Points



Trough #2

Bridge Creek ppt vrs sediment

All data Points

<u>linear regression</u>

a_0 = -.48

a_1 = 1.05

r^2 = .69

$S_{y.x}$ = 1.74

S_0 = .51

S_1 = .16

x	y
1	.57
5	4.77
10	10.02

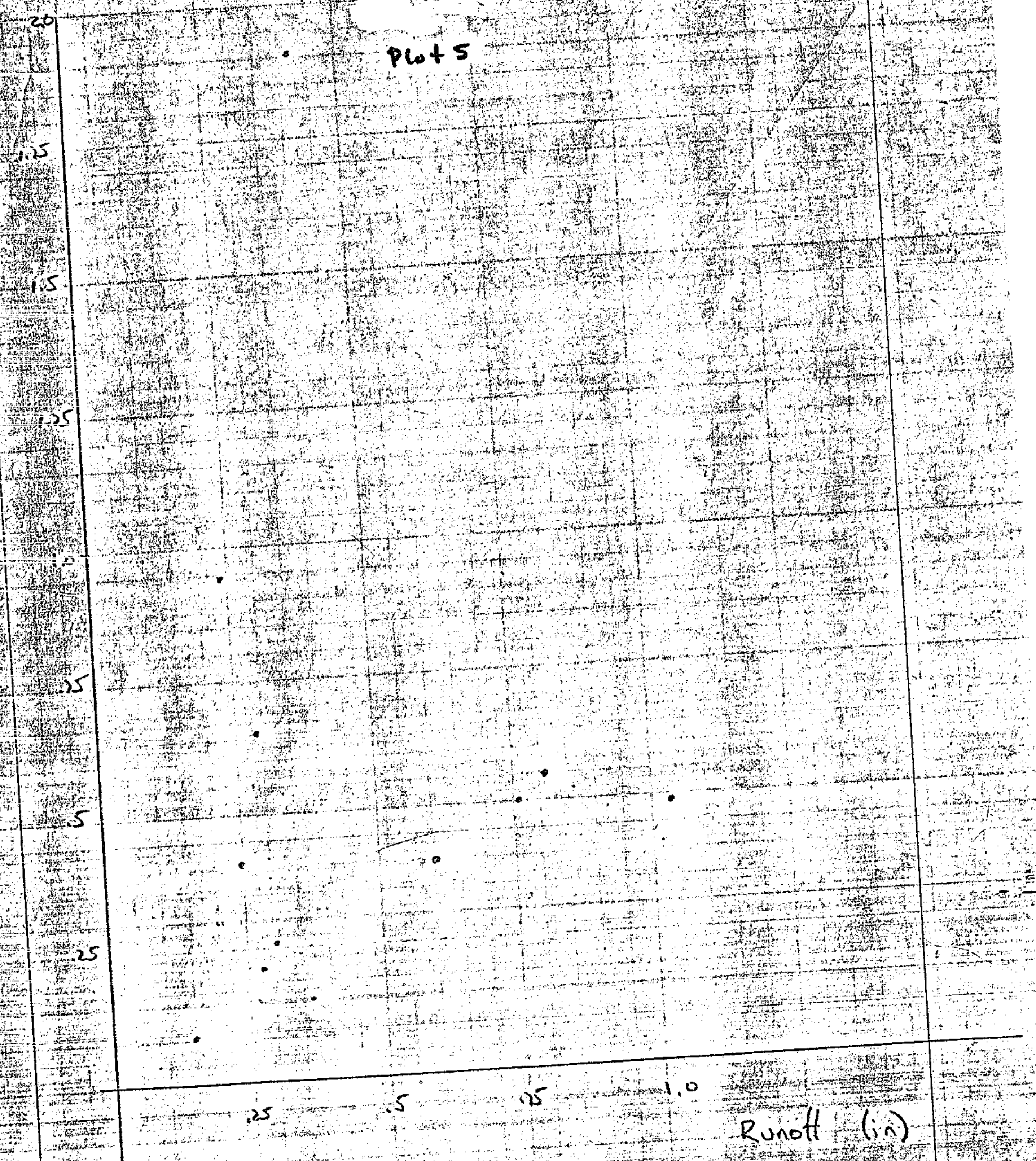
$y = -.48 + 1.05(x)$

Trough #2
All data points

	ppt	wt
1-15	8.86	13.38
1-17	1.08	.87
2-4	2.43	4.10
2-6	0.53	.22
2-14	4.75	5.62
2-20	1.03	.58
2-21	.56	.15
2-22	.50	.41
2-26	1.60	.65
2-28	2.68	.38
3-4	.59	.31
3-5	1.11	.85
3-6	.39	.94
3-18	8.66	4.55
3-21	1.25	.55
3-28	.44	.09
4-5	2.41	.82
4-8	.72	1.92
4-9	.94	.40
4-21	2.38	.48
5-27	2.60	.50

65

Trough #2
Runoff vrs Sediment
only R.O. Data



Trough #2
Runoff vrs Sediment
Only R.O. Data

Linear Regression

$a_0 = .51$

$a_1 = .08$

$r^2 = 2.12 \times 10^{-3}$

$s_{y \cdot x} = .51$

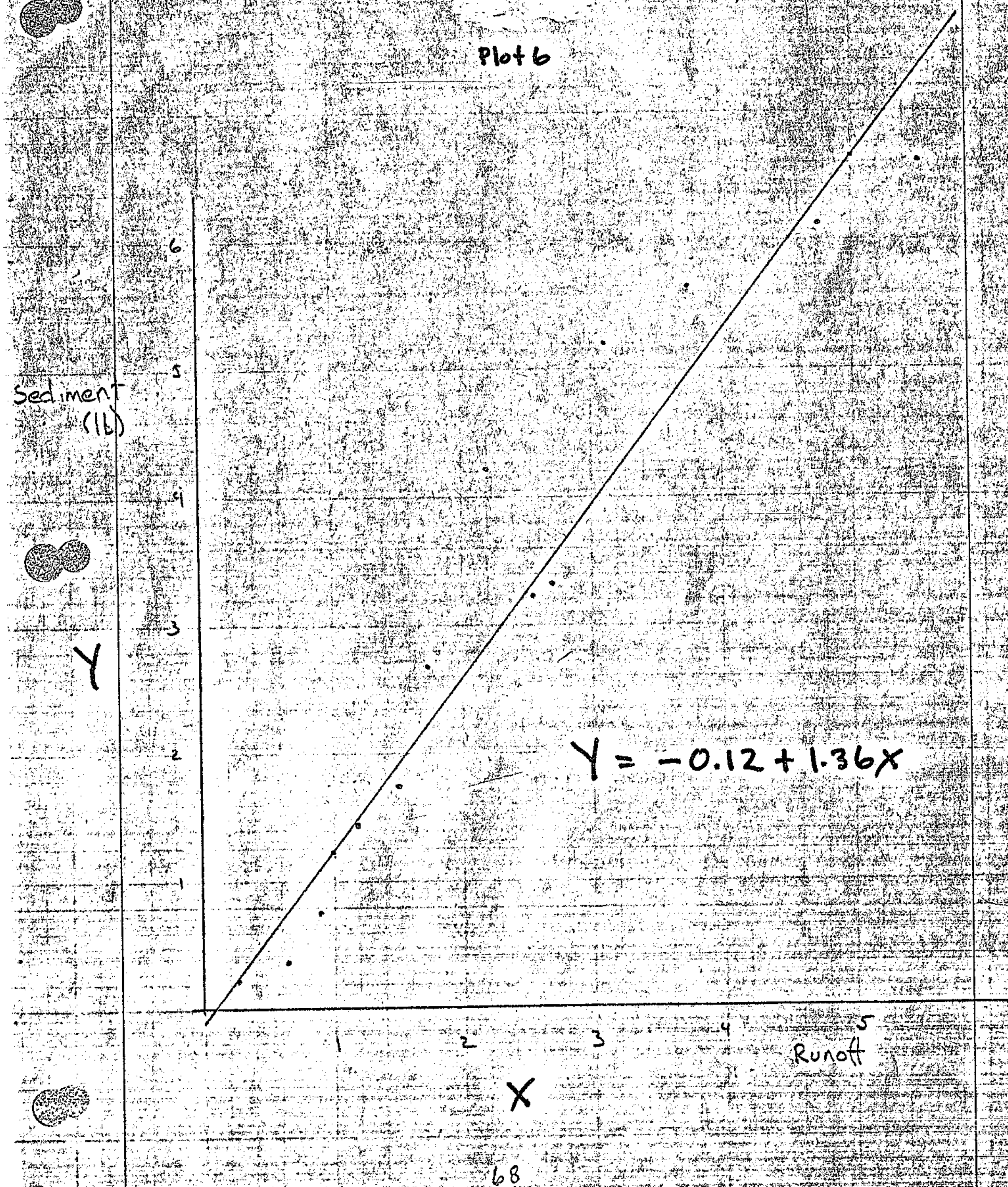
$s_0 = .3$

$s_1 = .56$

No correlation to speak of

Σ Runoff Vrs Σ Sediment

Only R.O. Data



68

Trough #2
Σ Runoff vrs Σ sediment
Linear Regression

a_0 = -.12

a_1 = 1.36

r^2 = .95

$S_{y.x}$ = .54

S_0 = .28

S_1 = .10

x	y
1	1.23
5	6.66

Drawn on gra[ph]

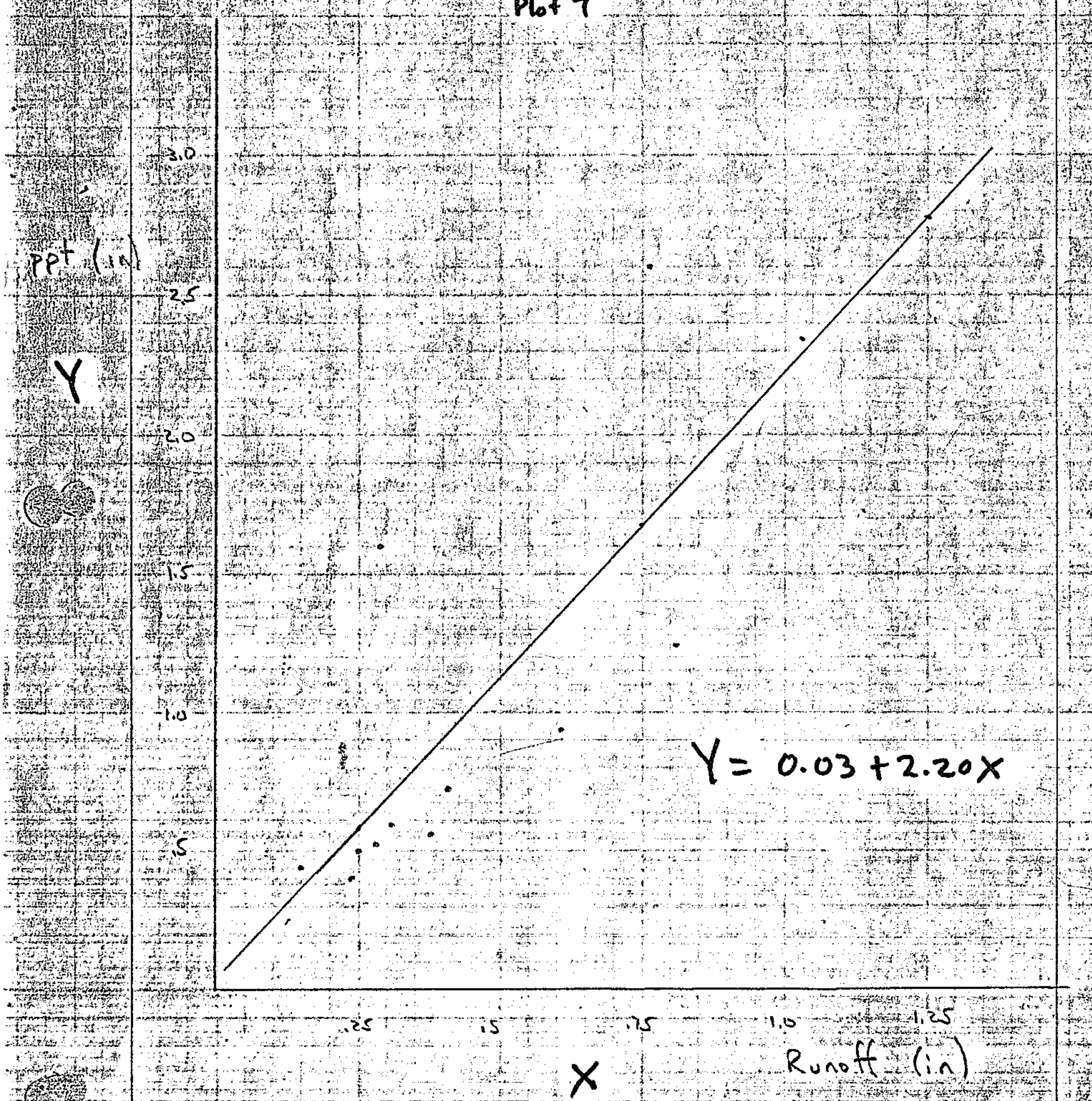
Equation $y = -.12 + 1.36(x)$

69

Trough #2

Rainfall Vrs Runoff

Only R.O. Data



Trough #2
Rainfall Vrs Runoff
Only R.O. Data

Linear Regression

a_0 = .03

a_1 = 2.20

r^2 = .63

$S_{y \cdot x}$ = .49

S_0 = .28

S_1 = .53

x	y
.25	.58
.75	1.68
1.25	2.78

Equation $y = .03 + 2.20(x)$

Rainfall v.s. Runoff

Trough #2

Parabolic Curve fit

$a_0 = .75$

$a_1 = -1.48$

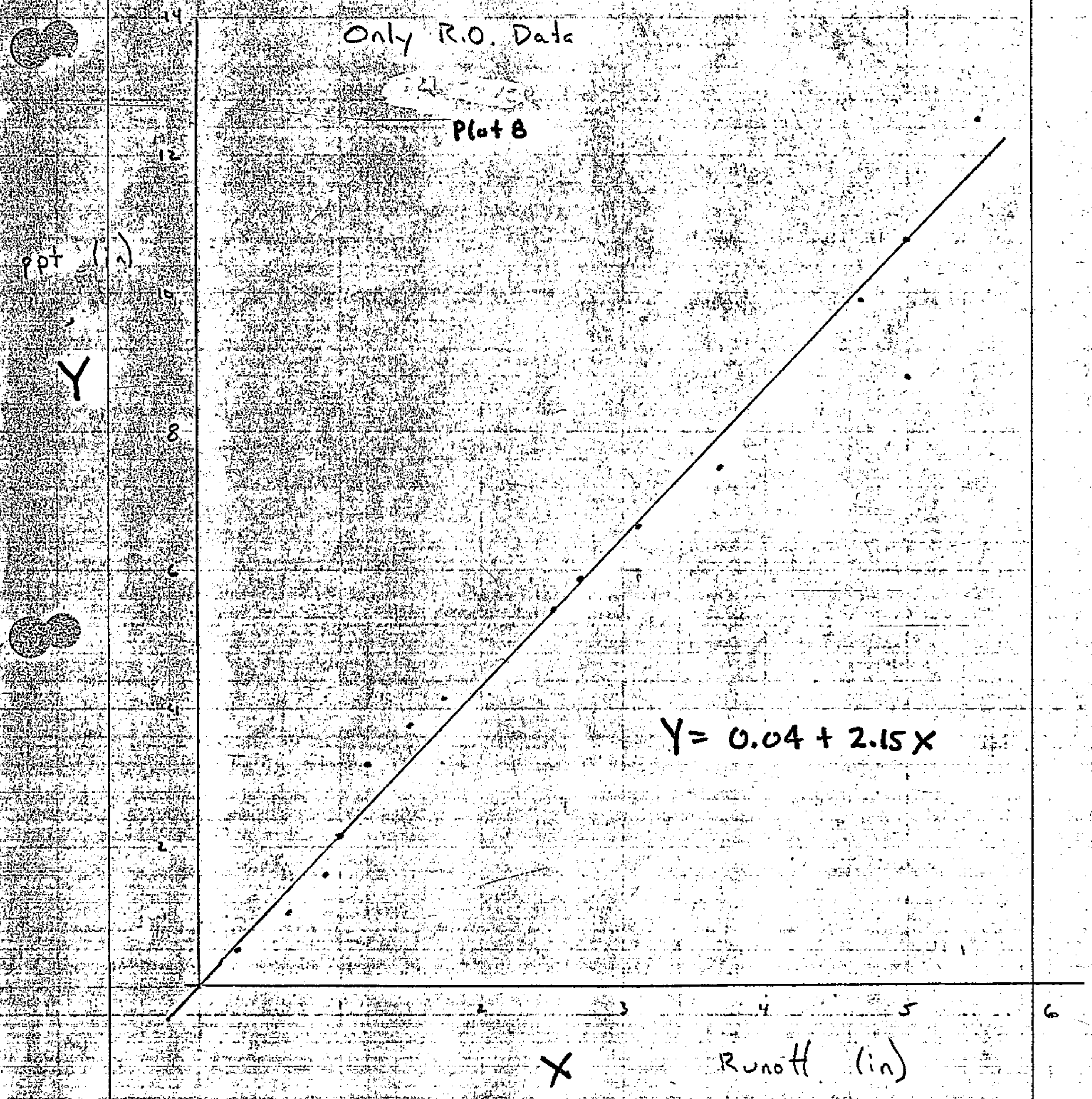
$a_2 = 3.73$

$y = .75 - 1.48x + 3.73x^2$

x	y
.25	.61
.5	.94
.75	1.73
1.0	3.00

Trough #2

Σ Rainfall Vrs Σ Runoff



Trough # 2
Σ Rainfall vrs Σ Runoff
Only R.O. Data
Linear Regression

a_0 = .04
a_1 = 2.15
r^2 = .99
$s_{y:x}$ = .43
s_{a_0} = .23
s_{a_1} = .08

x	y
1	2.2
2	4.3
3	6.5
4	8.7
5	10.8

Equation: $y = .04 + 2.15(x)$